

JULY 18, 1983

CHEMICAL & ENGINEERING

NEWS

Nuclear waste dilemma

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Cover: Electric heaters simulate thermal effects of nuclear waste on basalt rock tunnel at Hanford, Wash. Photo by Battelle Photography

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CHEMICAL & ENGINEERING NEWS

JULY 18, 1983

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Underground coal gasification is to undergo crucial tests that could result in opening up more coal reserves; test auto built for DOE combines gas engine and electric motor. Page 15

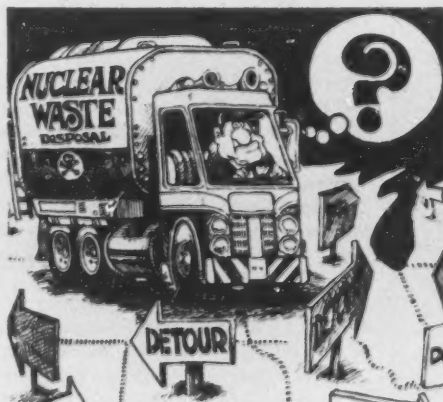
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Special Report

Finding sites for storing nuclear wastes has become a political time bomb; urgency generated by new waste law needs to be balanced by sagacity. Page 20

Key Tests Set for Underground Coal Gasification

National laboratory explores new methods that promise to open up more coal reserves, boost interest in coal-based synthetic fuels

Joseph Haggin, C&EN Chicago

Underground coal gasification (UCG) is about to undergo some crucial tests. Their successful conclusion would leave little doubt of the technique's technical feasibility and might even provide much needed economic impetus for some commercial ventures.

The tests, tentatively scheduled for late August, will be conducted by Lawrence Livermore National Laboratory (LLNL) near Centralia, Wash., in a coal seam owned by Washington Irrigation & Development Co. Three tests will check out a new UCG method being developed by LLNL.

Despite the on-again, off-again funding patterns in alternative (to oil and gas) fuel sources, UCG has managed to survive. Behind that survival is the dedication of a few believers and the irrefutable logic that it would be well to have a standby source of gas—both as competition to natural gas and as a well-developed technology—when natural gas reserves eventually become inadequate.

The declining appeal of coal mining, the inherent danger of mining, the escalating cost of extraction, and the somewhat limited reserves available to existing methods of mining have all held back any surge of interest in launching a new wave of coal extraction and conversion. There is no doubt that miners have been doing much to increase the yield of the mines each year. Bil-

lion-ton yearly totals have been reached, and that about fills present needs. The problem is that if alternatives to oil and gas are to be derived from coal, double, triple, and even greater multiples of present production probably would be required. Some observers doubt that this can be done without some dramatic changes in the way coal is mined and/or used. It is against this background that the building of a coal-based synthetic fuels industry is being carried out.

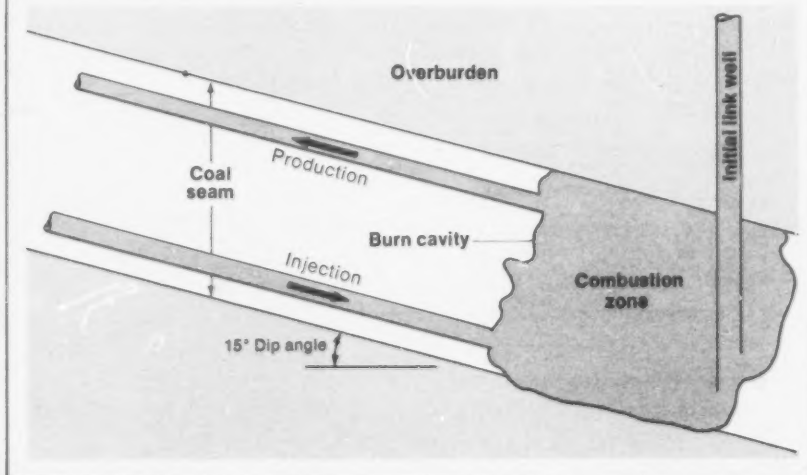
The U.S. development effort in UCG began in earnest in 1973 when the federal government began to fund tests. This came about the time of the Arab oil embargo.

Since 1973, 20 successful UCG tests have been conducted in the U.S. Of these, 15 have been funded by the federal government, mostly in the western part of the country. Also, the Soviet Union has expended considerable effort over the years at gasifying coal underground. Despite questionable results in many of the

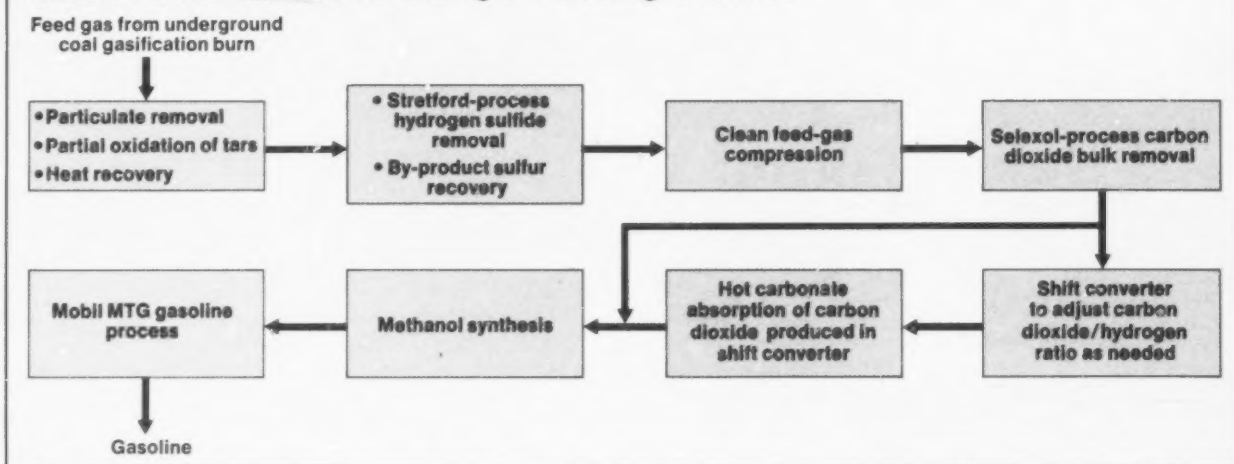
Soviet trials, and some teething troubles in the U.S. effort, UCG has finally emerged as a candidate for synfuels production. This is the view of Douglas R. Stephens, who directs the LLNL program. He justifies this on the basis that the economics of UCG appear to be competitive, that a much greater fraction of absolute coal reserves can be made available with UCG, and that the environmental impact of UCG is small.

The UCG product is a synthesis gas, usually classified as a medium-Btu gas that can be used directly as a fuel gas or as a feedstock for substitute natural gas (SNG). With suitable adjustments in composition—the carbon monoxide-to-hydrogen ratio—the syngas also may be used as feedstock for other chemicals, most notably methanol and gasoline. Although the economics may be disputed on occasion, Stephens suggests that medium-Btu fuel gas can be made from UCG sources for about \$4.35 per million Btu, and SNG for about \$6.25 per million Btu. If the

Coal burn will use improved controlled retraction injection point (CRIP) method



Gasoline could be made via underground coal gasification



syngas from a UCG burn is used for a Mobil-MTG plant, the product gasoline may cost as little as \$1.35 per gal. Excepting the price for gasoline, these are currently competitive prices in Stephens' view. In the case of methanol, current oversupply has depressed the price somewhat and this probably means that, in normal markets, UCG methanol would be easily competitive.

It has been estimated by various authorities that there are about 6 trillion tons of coal in the U.S. About 400 billion tons (6.7%) are available via conventional mining procedures. If UCG were employed, the amount of available coal could rise to about 1.8 trillion tons (30% of the total), says Stephens. Moreover, much of the coal in the increased total could not be mined by any other techniques, meaning that it would be unavailable under any other circumstances.

Aside from the inherent dangers in deep-seam mining, an overriding consideration in increasing coal use

has been environmental impact. In the case of UCG, most of the usual environmental problems have been bypassed, but there are some problems. One of the most notable is occasional subsidence below ground and occasionally up to the surface. In such tests as the Hoe Creek series in Wyoming held from 1978 to 1980, subsidence has not been extensive, but neither have been the tests. On the basis of experience so far, prediction of subsidence isn't very reliable, but the effects also appear to be less than might have been suspected.

Another potential environmental problem is groundwater contamination by the UCG combustion and pyrolysis products and the abrupt changes in geology that result from removal of the coal. In particular, the possible linking of various aquifers might be detrimental if some of them are brackish or if the links change the hydrology of the strata in question. LLNL and other agencies have car-

ried out some extensive tests before, during, and after a number of the UCG operational burns made to date. So far, there appear to be no real hazards, although all the data are not in.

The generation of potential pollutants in a UCG burn has been shown to occur. However, the natural adsorption properties of the overburden and underburden, in addition to the activated materials in the residual coal, tend to confine the possible pollutants to the immediate region of the burn.

At Hoe Creek and elsewhere, no great environmental impacts have been detected, but there are provisos. A very good geology survey is necessary before a burn, and extensive monitoring is required during and after the burn. This is usually enough to ensure minimal impact.

Traditionally, the technology of UCG has been rather low on the scale of sophistication, but that is changing. Through the efforts of the Department of Energy, LLNL, and such private operators as Gulf Oil, the Basic Resources division of Texas Utilities, and several foreign developers, the one great problem of controlling UCG burns and the many smaller problems gradually have become less perplexing.

Vertical wells, both for oxidant injection and product removal have been the historical standard, but are not always preferable. It is particularly difficult to maintain the integrity of a vertical injection well because of the threat of collapse of coal

Plant size affects cost of processing UCG gas to methanol

	4000 Bbl per day	12,000 Bbl per day	24,000 Bbl per day
Capital investment	\$66.2 million	\$130 million	\$200 million
Raw gas cost, per 1000 standard cu ft	49 cents	42 cents	37 cents
Annual operating expenses	\$29.2 million	\$ 71 million	\$123 million
By-product revenue, per year	\$13 million	\$ 39.1 million	\$ 78.2 million
Methanol gate price, per bbl	\$33.84	\$ 25.56	\$ 21.39

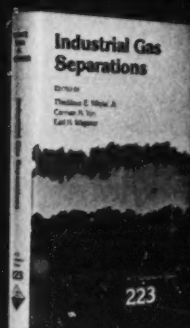
Note: 1981 dollars

and overburden. Failures of injection wells by plugging have been common. There has been less experience with horizontal injection wells, but they are considered to be more reliable. The principal cause of the troubles with injection wells has been the high temperatures in the pyrolysis zone. Production wells, by contrast, are easier to maintain because they can be cooled by steam and/or water injection to below the safe temperature of 500 °C.

The classic UCG burn is typically achieved by drilling two vertical holes into a seam that is either horizontal or slightly dipping. One hole serves for injection of air or oxygen to support combustion; the other conveys the pyrolysis/combustion products to the surface. As coal is consumed, the pyrolysis zone travels toward the injection well, and eventually the combustion either stops because the injection port is reached or because the well plugs. A classic operation includes a grid of wells, so drilled that the processes can be continued by repeatedly removing the injection wells along the grid as pyrolysis proceeds. In the case of a steeply dipping bed, the technique is more or less the same except that the injection and production wells become progressively shorter as pyrolysis continues.

A much-improved UCG system has been developed by Stephens and his associates at LLNL—the controlled retracting injection port (CRIP) method. In brief, the CRIP method requires two horizontal wells drilled along a coal seam. One is near the top of the seam and the other near the bottom. The bottom (injection) well is lined with metal pipe. The upper well is the production well. As pyrolysis proceeds, the burn cavity moves toward the base of the wells, progressively exposing more and more of the injection pipe. At an appropriate time, the pipe is melted or burned off and a new period of pyrolysis begins. In effect, the old problems of well plugging are circumvented by simply starting a new burn periodically along the horizontal wells. Experience so far has indicated that reliable gas flow control is afforded by CRIP, and the composition of the product gas is much more controllable.

Industrial Gas Separations



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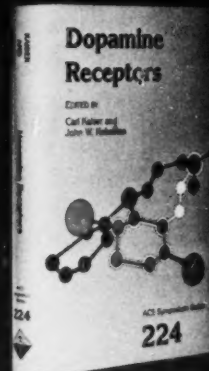
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Technology

The CRIP method was first tried successfully in early 1982 with a three-day trial, gasifying a 40-ton cavity. The injection pipe was then burned off and a second 10-ton cavity started. The original cavity cooled to 500 °C, and the second achieved the typical operating temperature of 1000 °C. The average heating values of the product gases were between 265 and 277 Btu per standard cubic foot.

In addition to the improvements in UCG technology afforded by the CRIP method, LLNL also has overcome one of the other minor but always vexing problems: how to reliably start a burn. The usual approach in the past has been to use electrical resistance heating to achieve the high pyrolysis temperatures, or, sometimes, to use incendiary chemicals and explosives. The method now in use by LLNL involves pyrophoric silane and propane gases. The silane ignites upon encountering the oxygen in the burn cavity and burns long enough to subsequently ignite the propane, which is injected into the well. The propane actually ignites the coal in the cavity. At a suitable time, the propane is shut off and the pyrolysis sustains itself. This method has proved reliable since its adoption.

The CRIP method will be used in the projected tests in Washington over the next three years. Each of the three tests will be of longer duration and of greater scope, culminating with a very large, whole-seam test. These tests follow a recent series of large block tests in the same Big Dirty seam at the Washington Irrigation mine, and earlier laboratory tests conducted on small blocks of coal encased in drums. The general thrust of the entire series has been to assess the scale factors that apply to UCG operations and to aid in the mathematical modeling of the UCG process in general. After much trial and some error, reasonably good agreement has been achieved between theory and experimental results.

In general, when a burn begins, the product gas heating value, chemistry, and thermal efficiency all are excellent. Up to 280 Btu per scf have been achieved with oxygen injection, and thermal efficiencies as high as 90% have been obtained. When the burn reaches the over-

burden, the heat loss increases sharply and heating value and thermal efficiency drop correspondingly. The CRIP method permits retention of the initial values by effectively preventing the burn from ever reaching the overburden.

With the expectation of a controllable, reliable UCG burn, the obvious next step is to integrate the gasification into a larger system. Two such systems that have received first consideration are the manufacture of methanol and the further conversion of the methanol to gasoline via the Mobil MTG process.

Pritchard Corp., Kansas City, has done some conceptual process design and has further studied the feasibility of using the raw gas from a UCG burn as a feedstock for methanol synthesis and/or MTG gasoline. The criteria for the studies were provided by LLNL, and the study called for three different sized plants—4000, 12,000, and 24,000 barrels per day of methanol. The 12,000-bbl-per-day plant is considered the baseline design, and the assumption is that a typical western coal deposit would be involved, in particular Sweet Water County in Wyoming.

In the Pritchard design, raw gas from the UCG burn is first run through a particulates separator and then undergoes partial combustion with controlled amounts of oxygen to eliminate potential catalyst poisons and to remove tars by converting them to gas. There also is catalytic conversion of carbonyl sulfides, sulfur dioxide, and nitrogen oxides. The gas is then sent to a Stretford unit for hydrogen sulfide removal and subsequent generation of elemental sulfur. Following a two-stage compression, the clean gas is then sent to a Selsol unit for removal of the bulk carbon dioxide. A shift converter adjusts the carbon monoxide-hydrogen ratio to the appropriate value required by the methanol synthesis process, and any carbon dioxide formed in the shift reactor is removed by hot carbonate scrubbing. The purified gas then goes to the methanol synthesis unit. Several processes may be used depending on local economics. The raw methanol is purified by distillation and then sold.

The conceptual process devised by

Pritchard may be altered to substitute a Mobil MTG plant for the final methanol purification units. The net products are gasoline and a few other associated hydrocarbons. The by-products of the process include elemental sulfur and carbon dioxide. The gasoline process would not be competitive unless at least the 24,000-bbl-per-day methanol plant could be used. For this size plant and larger ones, the economics of scale become considerable and even the gasoline is claimed to be competitive in price. □

Auto goes hybrid with gas-electric engine

A hybrid automobile, under development for some time by General Electric and others, has been completed. The one-of-a-kind test auto incorporates both an electric motor and a gasoline engine.

The hybrid car was designed to consume about 50% less gasoline than a conventional car of similar size over 11,000 miles of annual driving that consists of 10% city driving, with the balance on the open road. The two propulsion systems give the experimental vehicle the fuel savings of an electric one, since it runs entirely on batteries for most of the in-town driving. But it eliminates an electric vehicle's major drawback of limited range. With the gasoline engine, the hybrid can make long, even cross-country, trips without depleting its batteries.

Michael Ciccarelli, GE's program

manager for the hybrid vehicle project, calls the car a "technological insurance policy." It's aimed he says, at the day when the world's supply of petroleum runs low and gasoline prices rise sharply.

The hybrid car was built for the Department of Energy by a team of automotive and technology firms headed up by scientists and engineers at the GE Research & Development Center, Schenectady, N.Y. Among the major subcontractors, West Germany's Volkswagenwerk designed and built a specially modified, fast-starting 80-hp gasoline engine; Johnson Controls Inc., Milwaukee, supplied the 12-volt lead-acid batteries; and Triad Services Inc., Madison Heights, Mich., designed and fabricated the car's body and chassis, as well as constructed a full-size clay model used to make moldings from which particular body structures were cast. DOE's contract manager on the project was the Jet Propulsion Laboratory, Pasadena, Calif., to whom the car has been delivered for six months of extensive testing.

A key element in the car's operation is a microcomputer designed by GE that controls the entire hybrid system. The vehicle's 40-hp electric motor and 80-hp gasoline engine operate separately or in parallel, the electric motor employed primarily for speeds from zero to 40 miles per hour, and the gasoline engine for most highway driving. In situations in which both the electric motor and the gasoline engine are needed, such as in passing, the load is shared automatically. The microcomputer, reacting to the driver's "foot-pedal" commands, controls overall vehicle operation. It constantly monitors the battery pack's state-of-charge and other parameters and decides when to switch on the electric motor, the gasoline engine, or both.

The car's electric motor is powered by 10 batteries that weigh a total of 750 lb. The battery pack may be recharged by the gasoline engine when it is in operation or by wall-plug electricity using a specially designed on-board battery charger. The car also is equipped with a regenerative braking system that feeds recharge energy to the batteries when the brakes are applied. □

Nineteen get Searle scholar grants in 1983

Since the beginning of the Searle Scholars Program in 1980, 47 research investigators have received grants totaling about \$4 million for biomedical research. Nineteen more recipients have been named for 1983, each receiving \$157,000 for the next three years. The \$3 million in grants awarded in 1983 raises to about \$7 million the total funds distributed.

The Searle Scholars Program, which has more than \$50 million in monies available, was initiated under terms of the will of the late John G. Searle, former president of G. D. Searle & Co., the Skokie, Ill., pharmaceutical firm. Searle established several trusts, the income from which he directed to be used for research in medicine, chemistry, and the biological sciences. Searle's widow left additional funds in trust for the program. The trustees of Searle's will agreed that the best way to use the funds would be through research grants to newly established investigators, primarily in academic laboratories. The intention is to encourage younger investigators who show promise in their chosen fields of research.

Applicants for grants from the Searle Scholars Program have their proposals screened by an advisory committee, currently chaired by David Shemin, professor of biochemistry and molecular biology at Northwestern University. The recommendations of the advisory committee are then passed to the administrators of the program for action. Recommendations are made on the basis of the prospective recipient's being a scientist of recognized ability, who is likely to continue to make important research contributions in his or her chosen field. Grants are used with considerable flexibility, the major criterion being the best scientific judgment of the recipient.

The Searle Scholars Program is under the administrative control of the Chicago Community Trust, a community foundation established in 1915. Cedric L. Chernick, formerly vice president for sponsored programs at the University of Chicago, is director of the program. □



Hybrid car, built for DOE, is designed to save gasoline through battery use